136th Meeting of the Machine Protection Panel

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The slides of all presentations can be found on the website of the Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 Approval of MPP#135's minutes

- Actions from 135th MPP:
    - Define, plan and perform reliability run for the CIBDS V5. (ABT, MPE)
    - Check the timing of the CIBDS retrigger pulse so as to decide if we need to increase the TDU delay time of 270 µs for the CIBDS asynchronous beam dump trigger. Don't link in the electronics the A and B signals for user permits. (S. Gabourin)
    - Verify the reliability of the wire voltage measurement system (Adriana). Specify connection to WIC. (A. Rossi, J. Uythoven)
- No additional comments were received on the minutes; they are therefore considered approved.
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1.2 AOB - MKBH-C/B2 observed sparking activity after replacement of GTO stack - status and scenarios (S. Senaj)

- There were two MKB erratics in the recent past, therefore it was decided to clean all MKB generators, as dust contamination is a frequent cause for breakdowns with higher voltage. A reliability run, 16h with DC voltage as for operation at 7TeV, was performed after cleaning:
    - No problem on Beam 1.
    - A few sparks and an erratic of generator C on Beam 2 which retriggered its neighbours, B and D, 6 µs later. There was subsequent damage on a GTO stack.
- Cleaning might have been the cause of the sparking due to the presence of water in the alcohol used for cleaning.
- The generator D was replaced and after another reliability run now everything looks fine.
- An abundant black dust of unknown origin was observed around the stacks, from experience with the MKDs one can assume it is a very likely cause of the sparking. Potential sources of dust presence on the stack include: perforated panels, strong air flow from ventilation, manual switch to ensure protection of operator causing metal friction.
- The re-triggering lines are not supposed to behave this way; it is supposed to trigger the MKBs from the MKDs. A parasitic coupling was discovered

allowing triggering between MKBs, which is a new, potentially dangerous failure mode.
  - Daniel asked if a modification is foreseen.
    - Not until the results of the lab tests, for now just the supervision of the kickers.
- Some tests in the lab were performed, during which the GTO stack is connected to the generator chassis, which acts like an inductive divider. During this test a 70V transient was observed.
- Mitigation measures taken:
  - Short term: installing a scope to monitor sparking, regular inspections, using alcohol in pressurised cans to avoid humidity seeping in.
  - Mid-term: replacing the perforated panels (EYETS), cleaning the floor in the vicinity of the equipment, machining of sharp edges on the plates, inspection of all ross relays and replacement in case of need, tests of the coupling to the retrigger line which might result in cabling changes.
  - Long term: **Proposal: reduce voltage on MKBH**, which would imply less dilution in the H plane. Alternatively, install stacks with more GTOs to reduce the voltage /GTO (which would maintain the current dilution strength).
    - Jan commented the LHC should survive with only one MKB in each plane. Anton pointed out that the dump would maybe have to be changed after such an event. Especially, the windows have been identified as the most sensitive elements.
    - Wolfgang stated this is a new failure case for ABT and it has to be studied.
    - Markus observed that the sparking rate might be a threshold effect and sparking might disappear with a slightly lower voltage. It is better to lose 10% of the dilution kick all the time than 75% during an erratic.

Action: perform a reliability run with lower voltage during the EYETS and study these failure case. Determine the criticality of lower dilution as well as the failure of >=2 dilution kickers for the dump window and absorbers. (ABT)

  - Another long-term mitigation is the installation of real-time air pollution monitoring to identify the source of the black dust.
    - Jan asked for more details about the perforated plate replacement. A closed metallic plate will replace the currently perforated one. Jan asked if this was tested in the lab, it wasn’t but the temperature inside the cubicle is expected to reach only a few degrees more than in the MKDs.
    - Moreover, Jan suggested the scope could be the cause of the wrong re-triggering, another test without the scope will be done.
    - Markus asked for details on how the measurement is done, with high impedance scope inputs or using isolation

amplifiers? It is now done with 50 Ohms (for appropriate termination), which are floating.

- Daniel stated it is important to study this new failure case and if the scope is having any impact on this. More importantly to verify that one cannot trigger the MKDs that way, which would lead to an asynchronous beam dump and following maybe reduced dilution.

1.3 Damage levels of superconducting magnet components - status of studies and first experimental results (V. Raginel)

- In HL-LHC ultra-fast failures could cause energy densities of up to 100 J.cm^{-3} due to beam impact. Therefore, the project was commenced in MPE to assess the damage limits of superconducting magnet components. Furthermore, there are tighter collimator settings under consideration for 2017, which can increase the energy deposition in Q4 downstream of the TCDQ.
- The known damage mechanisms to superconducting magnets are:
  - Plastic deformation of the copper matrix, which can cause stress on the Nb-Ti and lower critical current.
  - Breaking of filaments, Nb-Ti is quite robust, but Nb_3Sn experiences much stronger performance degradation.
  - Melting the copper matrix, the limit is known to be ~6 kJ.cm^{-3}.
  - Reduction of the α-phase of the Ti in NbTi after few minutes above 500 °C, which causes a permanent reduction of the critical current.
- Another mechanism is the degradation of the Kapton insulation, literature suggests 400 °C as a limit. Degradation of the insulation can cause shorts, which are dangerous for the magnet.
  - Anton commented on the known degradation of Kapton due to total integrated radiation dose. Daniel answered that this knowledge could be combined with the results of this work in the future.
- An experimental plan was drawn up to identify the degradation of the insulation and the performance of the superconductor as a function of energy deposition:
  - Heating of cable stacks in a furnace
  - Pulsed heating of insulation and superconducting material
  - Experiments with beam to simulate all degradation effect together
- The 1st experiment allowed measuring the breakthrough voltage of the insulation and shows degradation after 400 °C. A model for the chemical reaction was developed and fits the experimental data. It was used to extrapolate to higher temperatures and very short time scales, which helped designing the following experiments.
- The 2nd experiment was conducted at the HiRadMat facility. 30 cable stacks and NbTi/$NbSn_3$ strands were exposed to impacts with the SPS 440 GeV proton beam. From the measured parameters of the beam and FLUKA simulations the energy deposition in the stacks and strands went from 100 J.cm^{-3} to 2000 J.cm^{-3}, i.e. 70 to 750 °C hotspot temperature. Once the

radioactive cool-down is finished (expected for beginning of December 2016) the experiment can be opened and the degradation insulation of the cables measured with HV measurements and the change in critical current of the conductor via magnetisation measurements.

- Conclusions: two experiments were conducted; more results will be available soon. More experiments are pending: the pulsed heating of Kapton and superconducting strands, and an experiment with beam shot on a test coil at cryogenic temperatures.
  - Anton asked if some thermo-mechanical simulations were performed to know, if the stress in the experiment could cause damage.
    - Vivien answered that from simulations one could know if copper plastifies, but not how the superconducting properties of the strands would change.
  - Anton added that the specific heat of copper is much lower at low temperatures, so for the same energy deposition the temperature rise can be a factor 4 higher at the cryogenic temperatures and therefore causing higher stresses. A cryogenic experiment is therefore very important.
    - Vivien added that this effect can be partially compensated be a much lower thermal expansion at cryogenic temperatures.
  - Stephane asked if it was planned to power the test coil for the cryogenic experiment.
    - Daniel answered that it is planned to add test coils, which can be powered *in situ*. As one cannot easily install a 12 kA power supply in HiRadMat it is planned to use test magnets with critical currents up to 1 kA.

AOB - Delay between CIBDS beam permit removal and TSU detection via long BIS path (S. Gabourin)

- A new version of the CIBDS will be implemented during the EYETS, the A and B channels will be separated. The CIBDS detects the loss of the beam permit on channel A and B and removes the user permit in the CIBU which then sends the asynchronous beam dump signal to the trigger delay unit (270 µs) and the synchronous dump signal to the synchronization unit. The CIBDS doesn't do any processing, it just passes the signal, which is important for its reaction time.
- For the short path, the synchronous signal can arrive up to 94 µs later and the asynchronous one 270 µs later. For the longest path (due to the routing of the fibers of the A and B loop), the synchronous signal could arrive 307 µs later, so after the asynchronous one. **Proposal: increase the asynchronous beam dump delay to 320 µs** to avoid asynchronous beam dumps in case the short path is broken.
  - Jan added this is for the case of an internal problem in the CIBDS so one would want to dump the latest possible, he doesn't see a problem with increasing the delay. Probably one should rather go to

350 us to ensure sufficient margin to maximum the synchronous dump delay

- The MPP approves the proposal to increase the trigger delay of the CIBDS from 270 us to 350 us during the upcoming EYETS.

Action: Transmit this proposal to Etienne Carlier and Nicolas Magnin so they can comment on the number. (S. Gabourin)

AOB - Result of test with DCCT and 24bit ADC, effect on SMP and plans for EYETS (S. Gabourin)

- The Beam Current Transformer measurement for the LHC will be upgraded from 16 to 24 bits for accuracy. This change affects the 4 links to the Safe Machine Parameter system. Tests were performed during TS3 and show it works well. Replacement will take place during the EYETS.
- This will need one full week of testing to ensure noise from the timing frame doesn't disturb acquisitions by the SMP. This should be part of SMP re-commissioning after the EYETS, in the first quarter of 2017.
  - Daniel asked what difference the SMP will see from this.
    - Before, there was an oscillation because of the rounding, now it would be more stable.

Action: Come back before or early during the EYETS with a testing plan. (S. Gabourin)

AOB – None

Next meetings on the 9th and 16th of December.